UCRL-MA-133867

ES&H manual

Environment, Safety, and Health

Volume II

Part 22: Emergencies, Earthquakes, Fire

Document 22.6 Exposure to Radiation in an Emergency

(Formerly H&SM S 33.03)

Recommended for approval by the ES&H Working Group

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New document or new requirements

Approval date: May 8, 1997

Minor revision, no new requirements

Approved by: The Hazards Control Department

Approval date: August 18, 2002

This work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-ENG-48

22.6

Exposure to Radiation in an Emergency*

Contents

* Minor Revision

22.6

Exposure to Radiation in an Emergency

1.0 Introduction

The Department of Energy's (DOE's) rule on occupational radiation protection (10 CFR 835, hereafter referred to as "the Rule") provides for emergency doses that exceed the limits for routine occupational exposure. These doses may only be incurred in cases where there is no practical or reasonable alternative and where the exposure will save human life, minimize significant exposure to others, or protect major property. ("Major property" is typically valued in excess of $100,000 and may include data and information.) In all cases, the dose shall be justified by the importance of the emergency task to be performed.

This document

- Provides guidance for responding to the emergency and assessing potential radiation doses.
- Specifies the activities and conditions under which emergency doses may be authorized, who may authorize such doses, and the level of Hazards Control Department concurrence required.

2.0 Hazards

Individuals who respond to radiological emergencies could receive radiation doses in excess of the routine occupational exposure limits. The assumed risk associated with chronic, low-level occupational radiation dose is an increased risk of cancer. The known risks associated with acute, high-level radiation doses can include radiation sickness and death.

Table 1 provides a summary of the health effects associated with various levels of acute whole-body doses. Similar doses to an extremity (e.g., the hand, forearm, or foot) or to a small part of the body (e.g., the throat, chest, or intestines) will result in less severe symptoms and a concurrent decrease in the mortality rate.

Table 1. Biological effect from acute whole-body doses.[a]

Dose range (rads)[b]	Biological effect	Survival[c]
50–100	Slight decrease in blood count; minor radiation sickness	Virtually certain
100–200	Symptoms of bone marrow damage; moderate radiation sickness	Probable (>90 %)
200–300	Moderate to severe bone marrow damage; serious radiation sickness	Possible— • Lower third of range: $LD_{5/60}$ • Middle third of range: $LD_{10/60}$ • Top third of range: $LD_{50/60}$
350–550	Severe bone marrow damage; extreme radiation sickness	Death within 24–42 days • Bottom half of range: $LD_{90/60}$ • Top half: $LD_{99/60}$
550–750	Severe bone marrow damage; moderate intestinal damage; extreme radiation sickness	Death within 14–21 days
750–1000	Combined gastrointestinal and bone marrow damage; extreme radiation sickness	Death within 7–17 days
1000–2000	Gastrointestinal damage; early transient incapacitation; gastrointestinal death	Death within 5–12 days
2000–3000	Gastrointestinal and cardiovascular damage	Death within 2–5 days

a James J. Conklin and Richard I. Walker, Eds. Military Radiation (Academic Press Inc., New York, 1987), pp. 165–190.

b For acute effects, doses are measured in rads. Routine occupational dose (formally referred to as "dose equivalent" and measured in "rem") is the product of the dose delivered (measured in rads) and the radiation-weighting factor of the radiation delivering the dose. The radiation-weighting factor is 1 for beta and gamma radiation, 20 for internally deposited alpha radiation, and varies between 1 and 11 for neutron radiation, depending on the energy of the radiation. Routine internal doses are calculated by assessing how much dose the person will receive over the next 50 years as a result of the uptake and are recorded in "rem" as "committed effective dose equivalents."

Radiation-weighting factors should NOT be applied to acute doses in excess of 25 rads because the body's normal repair mechanisms may not function normally when dealing with large doses and because nonstochastic effects (i.e., those due to cell killing) usually override the deterministic effects (i.e., those associated with an increased risk of cancer). Similarly, the "50-year dose" is also not appropriately used to assess the acute consequence of an internal exposure.

c $LD_{x/y}$ = Lethal dose to "x" % of the population within "y" days of receiving the dose (assuming no medical attention).

3.0 Controlling Exposure to Radiation in an Emergency

3.1 Actions Required During an On-site Emergency

During an on-site emergency, the senior on-scene person present (i.e., the individual with the highest level of authority) shall direct the emergency response until relieved by the Fire Department Incident Commander (IC). Thereafter, the senior on-scene person shall act as a resource to the IC. Throughout the emergency, the ES&H Team shall act as a resource to the person directing the emergency response (i.e., the IC or the senior on-scene person.)The person directing the on-site emergency response shall

- Request additional resources, if necessary. Call 911 for Fire Department assistance or to obtain help from the Hazards Control Department's Emergency Assistance (EA) Team. The EA Team can supply contamination control and hot-line services.
- Identify tasks critical to the emergency response. Critical tasks may include saving lives, protecting major property, protecting large populations, securing critical equipment, retrieving nuclear accident dosimeters (NADs), and rectifying conditions that could otherwise escalate and cause unacceptable injury or impact. Facility workers who were present at the time of the emergency are an excellent resource for identifying critical tasks.
- Minimize the risk of injury to individuals involved in rescue and recovery operations
- Weigh actual and potential risks against the benefits to be gained . Use the emergency dose guidelines in Table 2 to determine the maximum dose recommended for various types of operations.
- Establish boundaries that delineate hazardous zones. Ask the ES&H Team health and safety technician or health physicist to determine the radiation dose rates and, where possible, the concentrations of airborne radioactive material in areas where emergency operations need to occur.
- Regulate the movement of personnel across established boundaries. The EA Team can provide assistance.

Table 2. Emergency dose guidelines.

Whole-body dose (rem)[a–b]	Activity	Condition	Minimum authorization level in absence of the IC[d]	Minimum concurrence level in absence of the IC[d]
<5	All	Any emergency	Person receiving the dose	—
5–10	Lifesaving or Protection of large populations or Protection of major property	Only on a voluntary basis to someone who • Has completed Radiological Worker training, and • Has been briefed about the hazards, and • Does not have a medical condition that would be adversely affected by the emergency response.	Senior on-scene person	Health and safety technician
>10	Lifesaving or Protection of large populations	Only on a voluntary basis to someone who • Has completed Radiological Worker training, and • Has been briefed about the hazards, and • Does not have a medical condition that would be adversely affected by the emergency response, and • Is fully aware of the risks involved.	Senior on-scene person	Health physicist or ES&H Team leader

a The dose is allowed only if lower dose limits are not practicable.

b The guideline for dose to the lens of the eye is 3 times the listed values.

c The guideline for dose to the skin of the whole body and the extremities is 10 times the listed values.

d The Fire Department's IC has legal authority to act autonomously and does not need anyone's concurrence to authorize emergency doses greater than 5 rem. During nonemergency conditions, program managers are the authorizing individuals.

Once the decision has been made to have emergency responders re-enter the affected area, the person directing the emergency response shall

- Establish the time limits for response in affected areas. Figure 1 shows the integrated dose as a function of the dose rate and exposure time. The health physicist or, in his or her absence, the health and safety technician can assist in calculating stay times.
- Develop an operating schedule for tasks in areas where responders could receive individual doses greater than 5 rem.
- Establish a contingency plan in case the working area conditions are significantly different from those anticipated or if the tasks cannot be accomplished.

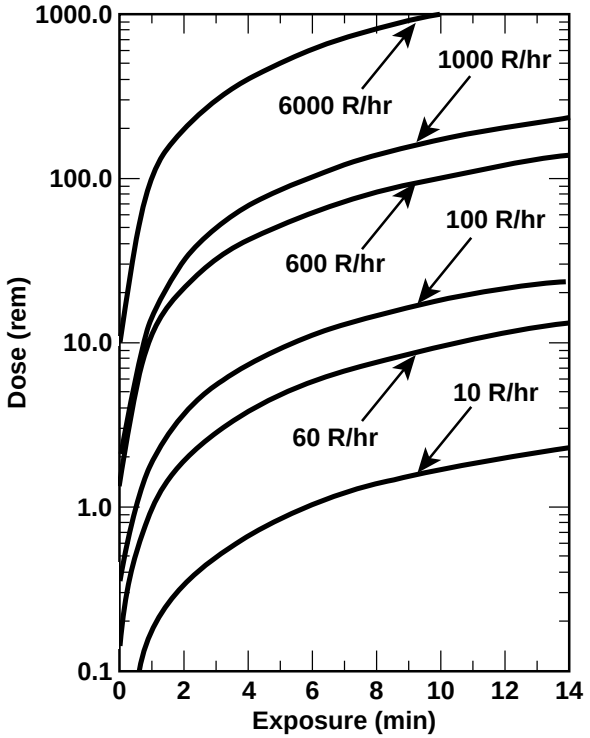

Figure 1. Guide for determining the dose and exposure time during an emergency. Assume that an exposure of 1 R will produce a dose of 1 rem.

- Ask for volunteers for any tasks that may result in individual doses greater than 5 rem. No individual shall be required to perform rescue actions that might involve substantial personal risk . Furthermore, it is LLNL's policy to
  - — Avoid using volunteers with known medical conditions (e.g., pregnancy, immune disorders, diabetes, a heart condition) that might be negatively impacted by the response.

— Use older volunteers because the latent effects of radiation exposure (i.e., cancer) may not be expressed for 20 years or more.

- Assign specific tasks to volunteers.
- Ensure each volunteer is wearing some type of radiation dosimeter. Volunteers should wear electronic dosimeters (e.g., Electronic Pocket Dosimeters (EPDs), chirpers) or pocket ionization detectors (e.g., pencil dosimeters), if available. Survey instruments used in the 'integrate' mode can also be used to estimate dose provided they do not interfere with the operation and are appropriate for the radiation field. 'Turn-back' levels should be established when integrating dosimeters or instruments are used.
- Supervise the exposure time of responders entering areas where individual doses may exceed 5 rem.

3.2 Estimating Potential Radiation Doses

Radiation dose-rate information obtained during an emergency is generally not as accurate as information obtained under more ideal conditions because

- There may be significant fluctuations in the actual dose rate.
- The dose rate may not be uniform from one area to another.
- There is generally not enough time to conduct a thorough survey.
- The accuracy of dose-rate measurements are limited by the accuracy of the instrument used to measure the dose.

Therefore, when determining stay times based on dose rate measurements, assume the calculated dose may be low by 50–100%. For example, if the measured dose rate is 100 rem/h and the stay time is 6 minutes (0.1 h), the calculated dose is 10 rem. Assume the actual dose to the responder will be 50–100% higher, or 15–20 rem.

3.3 Authorizing Emergency Doses

From both an injury and a radiation dose standpoint, the decision to rescue a person from a high-radiation field should be made promptly to maximize the injured person's chance of survival. Rescue may only be authorized if

- It is possible to estimate the dose to responding personnel.
- The dose can be justified by the activity to be performed.
- The risk of injury to individuals involved in the rescue and recovery operations is minimized .

For lifesaving operations, consider the dose the victim has already received and the dose he or she may be still receiving. For example, if a victim has already received more than 800 rads, there is little chance of saving his or her life and therefore little point in exposing emergency responders to doses greater than 25 rem. Emergency doses should NOT be authorized to recover the body of a deceased person. This type of recovery should be made under more planned conditions.

As a general guideline, when acting to protect large populations, the *collective dose* that emergency responders receive as a result of a planned action should not exceed the collective dose they are averting by that action. For example, if the response will likely result in a collective dose of 20 rem to the responders, but will only avert a collective dose of 1 rem to the population, the exposure is not warranted. However, if a 20-rem dose to the responders will avert a collective dose of more than 100 rem, then the exposure might be warranted.

The decision to authorize a dose to emergency responders to avert additional onsite or offsite dose may be difficult, largely because the magnitude of the dose already received and the potential dose averted will likely be unknown. The amount of dose authorized in such cases should be commensurate with the potential for averting *additional* doses, taking into account the magnitude of dose already received by the population. For example, it may make sense to authorize a 10 rem dose to an emergency responder to avert a collective 10 rem offsite dose. However, it may not make sense to authorize the same dose if the population has already received a dose of 100 rem, and only an additional dose of 10 rem would be averted.

The level of concurrence needed to authorize emergency doses depends on the level of dose that may be received. Table 2 provides guidelines for authorizing emergency doses.

3.4 Training Requirements

Any volunteer authorized to perform emergency actions that may result in an effective dose exceeding 5 rem shall have completed Radiological Worker training [HS6010 (Radiological Worker) or equivalent or HS6940 (Radiation Safety for Emergency Personnel)] and shall be briefed before the emergency response to the known and anticipated hazards to which he or she may be exposed.

As appropriate, the Hazards Control Department shall refer individuals who receive a dose in excess of 5 rem to the Health Services Department for medical evaluation and counseling.

3.5 Actions Required Following an Emergency Exposure

An individual who receives more than 5 rem as a result of an authorized emergency exposure may be permitted to return to work in radiological areas during the current year, provided that all of the following conditions are met:

- LLNL management and the head of the responsible DOE field organization grant approval.
- The individual receives counseling from radiological protection and medical personnel regarding the consequences of receiving additional occupational exposure during the year.
- The individual agrees to return to radiological work.

All doses resulting from emergency exposures shall be recorded in the affected individual's occupational dose record. Doses from emergency responses shall be recorded separately from routine occupational doses.

When the emergency exposure conditions have been eliminated, LLNL management shall notify the head of the responsible DOE field organization. Normal operations may resume only with the approval of DOE.

3.6 Responding to Off-site Emergencies

LLNL personnel may respond to off-site emergencies as part of DOE's emergency response program (e.g., the Radiological Assistance Program (RAP), Accident Response Group (ARG)). A typical offsite response includes a lead LLNL individual, a DOE Team Leader, and an IC who may be military, civilian, or a state or federal employee. The DOE team acts at the request and discretion of the IC. The LLNL team acts at the request and discretion of the DOE Team Leader. All LLNL issues and actions should be coordinated through the lead LLNL individual. Although the local IC can authorize emergency exposures to any responder (without consulting the DOE team leader or the lead LLNL individual), LLNL employees should consult with the lead LLNL individual prior to knowingly receiving an emergency dose in excess of the annual dose limits. The lead LLNL individual, working through the DOE team leader, may offer their services as a resource to the IC regarding matters of radiation exposure.

3.7 Summary

Individuals directing a response to emergency situations involving radiation should remember the following:

- Large measurement errors may be associated with field measurements of high-radiation dose rates.

- High radiation doses can cause serious illness and death. See Table 1 for details.
- In the absence of the Fire Department's IC, doses greater than 5 rem may only be authorized by specific individuals and shall have the concurrence of the Hazards Control Department (see Table 2 for details).
- Individuals who may receive greater than 5 rem in an emergency response shall be volunteers who have completed Radiological Worker training [course HS6010 or equivalent or HS6940 (Radiation Safety for Emergency Personnel)] and have been briefed about the risks involved.
- Doses greater than 10 rem are only authorized to save a human life or to protect large populations. The volunteer shall be fully aware of the risks involved.
- If they so choose, individuals who receive a dose in excess of the occupational dose limit as a result of an authorized emergency exposure may return to radiological work only with the approval of LLNL and DOE.

4.0 Responsibilities

4.1 Senior On-scene Person

The senior on-scene person shall direct the emergency response until relieved by the Fire Department IC. Emergency response actions include

- Controlling access to the area.
- Requesting additional resources, as necessary.
- Establishing the response priorities.
- Authorizing individual emergency doses using the guidelines in Table 1.
- Relinquishing control of the emergency scene to the Fire Department IC and, thereafter, acting as a resource to the IC.

4.2 Hazards Control Department

If a Hazards Control Department employee is the first to respond to an accident scene, he or she shall assume the role of the senior on-scene person. Otherwise, the Hazards Control Department shall act as a resource to the person directing the emergency response. The senior Hazards Control Department person shall coordinate and direct the actions of other Hazards Control Department personnel present.

Emergency response actions typically carried out by the Environment, Safety, and Health (ES&H) Team include

- Conducting contamination surveys on evacuated personnel.
- Surveying the NADs worn by evacuated personnel to identify those who may have been exposed to a criticality accident.
- Establishing and maintaining contamination control boundaries.
- Assisting in the re-entry to the area.
- Consulting with the senior on-scene person prior to the authorization of an emergency dose in excess of 5 rem.

4.3 Fire Department

Upon arrival on the scene, the IC shall assume control of the emergency. Whenever possible, the IC should consult with a Hazards Control Department health physicist before authorizing doses in excess of 5 rem.

5.0 Work Standards

10 CFR 835, "Occupational Radiation Protection."

6.0 Resources for More Information

6.1 Contacts

For more detailed information on the issues discussed in this document, refer to the local self-help plans or facility safety plans or contact any of the following individuals:

- Program supervisor.
- Authorizing individual (facility or program manager).
- ES&H Team or off-shift health and safety technician.
- ES&H Team health physicist.
- ES&H Team leader.
- Hazards Control Department Radiation Protection Program Subject Matter Expert (RPP-SME).

Hazards Control Department personnel can be reached through the ES&H Contact List.

6.2 Applicable Lessons Learned

The "Radiation Protection" category of the Lessons Learned Program contains information pertinent to radiological emergency response. The Lessons Learned Program is available on the Internet at the following URL address:

http://www.llnl.gov/ es_and_h/lessons/lessons.shtml

6.3 Other Sources

For additional information about topics discussed in this document, refer to the *ES&H Manual*, available at the following Internet address:

http://www.llnl.gov/es_and_h/esh-manual.html

In particular, refer to the following documents in the *ES&H Manual*:

- Document 20.1, "Occupational Radiation Protection."
- Document 20.2, "LLNL Radiological Safety Program for Radioactive Materials."
- Document 20.3, "LLNL Radiological Safety Program for Radiation-Generating Devices."